Title:

PROCESS AND APPARATUS FOR PURIFYING IMPURE WATER USING MICROFILTRATION OR ULTRAFILTRATION IN COMBINATION WITH REVERSE OSMOSIS

Field of the Invention

The invention relates to a method and apparatus for the production of pure or potable water from impure water, brackish water or seawater. More particularly, the method and apparatus relate to the use of micro-filtration and/or ultrafiltration in combination with reverse osmosis.

Background of the Invention

Many methods and devices are known in the prior art for producing drinking water from contaminated water or seawater.

Such prior art devices typically include a form of pre-filter, such as an ultrafiltration (UF) or micro-filtration (MF) unit or particulate matter pre-filter, in conjunction with a reverse osmosis filter. The pre-filter serves to remove particulate matter, such as organic and/or insoluble particulate matter and thus protects the reverse osmosis filter from destruction. The reverse osmosis filter acts to remove ionic components, such as dissolved salts from seawater.

One of the inherent problems in using UF or MF membrane filters to pre-filter water prior to reverse osmosis treatment is that such filters can become clogged with particulate matter. This is especially the case in those systems where the filtrate is extremely impure and/or in large volumes, which is particularly the case where seawater is being filtered. It therefore becomes necessary to clean such filters periodically and the simplest method of doing this is by backwashing the filters. Backwashing involves reversing the flow across the filter to force and solid or particulate matter which has

become entrapped in the filter cavities back into suspension. Normally, a portion of the reverse osmosis feedwater, which as already passed through the UF or MF membrane, is used to backwash the membrane filter.

Usually only 50-90% of the reverse osmosis feed actually passes through the reverse osmosis membrane to become desalinated reverse osmosis product, i.e. potable water, so losses to backwashing are acceptable.

It is also known in the prior art to use the residual reverse osmosis feed that does not pass through the membrane i.e. the reverse osmosis reject or reverse osmosis concentrate as the backwash source for the membrane backwash. This is disclosed, for example in US 6,120,688 where a portion of the reverse osmosis feed is redirected into a CIP (Cleaning In Place) tank which can from time to time be used to provide a flow to a micro-filtration module in a reverse direction to backwash the membranes.

However, there is an inherent problem with such an approach, namely that the reverse osmosis concentrate can form scales or particles due to the concentration effects of the reverse osmosis process. Alternatively, it is possible that there is biological growth on the reverse osmosis membrane surface which can likewise contaminate the reverse osmosis concentrate. Such particles or biological material could in fact foul the clean or filtrate side of the micro-filtration or ultrafiltration membranes of residual reverse osmosis feed is used directly to backwash the micro-filtration or ultrafiltration membranes.

It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

Summary of the Invention

According to a first aspect, the invention provides a method of purifying impure water contaminated with a filterable impurity and a dissolved impurity, the method comprising the steps of:

providing impure water to a primary microfiltration or ultrafiltration unit to remove the filterable impurity and produce impure filtered water contaminated with a dissolved impurity;

providing the impure filtered water contaminated with a dissolved impurity to a reverse osmosis unit to produce a potable water stream and a residual reverse osmosis stream; and

treating the residual reverse osmosis stream prior to reuse.

Preferably the residual reverse osmosis stream is treated prior to reuse to backwash the primary microfiltration or ultrafiltration unit.

Preferably the residual reverse osmosis stream is treated prior to reuse by being passed through a secondary filter. The secondary filter is preferably a microfiltration or ultrafiltration membrane, and may be in the form of a cartridge, sand, pre-coat, or other media filter. The secondary filter may be disposable, or it may be backwashed or backwashable.

Preferably the residual reverse osmosis feed is used to backwash the primary microfiltration or ultrafiltration unit and is subject to ultrafiltration or microfiltration by a secondary ultrafiltration or microfiltration unit prior to said backwashing.

Preferably the secondary filter comprises multiple stages of filtration. More preferably the multiple stages of filtration include a first filtration through a coarse filter prior to filtration through a membrane filter.

Preferably the reverse osmosis reject is in controllable fluid communication with coarse backwashable filters such as single or multimedia filters, disc filters, diatomaceous earth filters, membrane filters, strainers, or screens.

As used herein, "insoluble impurities" include those typically found in sea water and other natural bodies of water, and include organic and inorganic matter, particulate matter, biological and non-biological matter etc. The term "dissolved impurities" includes for example, dissolved, soluble or solubilized organic or inorganic matter. Most typically, of course, in seawater the greatest quantity of these will be sodium ions and chloride ions.

The term "comprising" is used in an inclusive sense, i.e. "including", rather than in an exclusive sense, i.e. "consisting of".

The residual reverse osmosis stream may be treated prior to being reused, in addition to, or as an alternative to, being passed through a secondary microfiltration or ultrafiltration membrane, by one or any combination of the following treatments:

- Chemical treatment, for example chlorination, fluorination, disinfection, scale control treatment, water softening (i.e. with lime), peroxide, sulfite/bisulfite, ozone or the like.
- Radiation treatment, for example, UV, IR, microwave
- Physical treatment, for example, ultrasonication or vortexing,
- Other treatments, such as heat, electropreciptiation, magnetic treatments etc.

According to a second aspect the invention provides a method of purifying impure water, the method comprising the steps of providing a primary microfiltration unit, a reverse osmosis unit, said reverse osmosis in downstream fluid communication from said primary microfiltration or ultrafiltration unit, and a controllable fluid pathway for directing residual reverse osmosis feed to backwash said microfiltration unit and

wherein the residual reverse osmosis feed is further subjected to ultrafiltration or microfiltration by a secondary ultrafiltration or microfiltration unit prior to a step of backwashing the primary ultrafiltration or microfiltration membrane.

Preferably the reverse osmosis reject used to backwash the filter has a suspended solids content of less than a predetermined quantity.

Preferably the reverse osmosis reject used to backwash the filter has a suspended solids content sufficient to allow it to be returned to the impure water source

Preferably the reverse osmosis reject used to backwash the filter has a suspended solids content sufficient to allow it to be returned to the ocean

Preferably the suspended solids content is controlled by controlling desalination recovery rate.

According to a third aspect the invention apparatus for purifying impure water contaminated with a filterable impurity and a dissolved impurity, the apparatus comprising:

a primary microfiltration or ultrafiltration unit to remove the filterable impurity;

a reverse osmosis unit to produce a potable water stream and a residual reverse osmosis stream;

said reverse osmosis in downstream fluid communication from said primary microfiltration or ultrafiltration unit;

a controllable fluid pathway to transfer impure filtered water contaminated with a dissolved impurity from the primary microfiltration or ultrafiltration unit to the reverse osmosis unit; and

means for treating the residual reverse osmosis stream prior to reuse.

Preferably the residual reverse osmosis stream is directed by a controllable fluid pathway to backwash the primary microfiltration or ultrafiltration unit.

Preferably the residual reverse osmosis stream is directed by a controllable fluid pathway through a secondary microfiltration or ultrafiltration membrane to backwash the primary microfiltration or ultrafiltration unit.

Thus in another preferred aspect the invention provides apparatus for purifying impure water contaminated with a filterable impurity and a dissolved impurity, the apparatus comprising:

a primary microfiltration or ultrafiltration unit to remove the filterable impurity;

a reverse osmosis unit to produce a potable water stream and a residual reverse osmosis stream;

said reverse osmosis unit in downstream fluid communication from said primary microfiltration or ultrafiltration unit;

a controllable fluid pathway to transfer impure filtered water comprising a dissolved impurity from the primary microfiltration or ultrafiltration unit to the reverse osmosis unit; and

a conduit to transfer a residual reverse osmosis stream from the reverse osmosis unit to backwash the primary microfiltration or ultrafiltration unit via a secondary microfiltration or ultrafiltration unit.

The apparatus may also include, in addition or alternatively to the above secondary microfiltration or ultrafiltration membrane, one or any combination of the following:

- Ports for the introduction of chemical agents such as chlorination agents, fluorination agents, disinfecting agents, scale control treatment agents, water softening agents (i.e. with lime), peroxide, sulfite/bisulfite, or the like;
- Ports for the introduction of treatment gases, such as chlorine or ozone
- Irradiation means such as UV light, IR, microwave sources

- Ultrasonic generators, vortexing devices, heating elements, electroprecipitators, magnetics etc.

The present invention also provides a separate backwashable or disposable cartridge microfiltration or ultrafiltration system for filtering residual reverse osmosis feed that is used for micro-filtration or ultrafiltration backwash in order to prevent particulate fouling of the clean or filtrate side of the micro-filtration or ultrafiltration membrane.

Further, the invention provides in certain desalination applications, a method of filtration of the residual reverse osmosis feed which requires multiple stages of filtration. Such multiple stages include a first filtration through a coarse filter prior to filtration through a membrane filter and further allow the use of filtered residual reverse osmosis reject to backwash coarse backwashable filters such as single or multimedia filters, disc filters, diatomaceous earth filters, membrane filters, strainers, or screens.

Currently, filters used to remove suspended solids from water that is subsequently desalinated, must be oversized in order to provide adequate filtered water necessary to backwash or clean the filter. Using the waste stream from a reverse osmosis desalination process for filter backwash or cleaning allows for the construction of a smaller filtration system since it needs to only satisfy the reverse osmosis feed requirements.

Further, using reverse osmosis concentrate for filter backwash reduces the overall wastewater volume from the combined filter/reverse osmosis facility and makes possible a configuration that reduces or eliminates the amount of sludge. The cost involved in dealing with sludge is a significant contributor to the overall operations and maintenance costs of desalination plants. The sludge needs to be settled, thickened and dewatered.

Due to high salt levels, it is not readily amenable to use as a soil treatment and so will require specialised transport and disposal.

In some circumstances where the desalination facility is permitted to discharge reverse osmosis concentrate back into the ocean or other receiving body of water it is usually permitted to allow a certain amount of suspended solids to be included in the wastewater typically 30-50mg per litre. By using reverse osmosis concentrate for backwash of the filters it is possible to achieve direct discharge of the backwash waste with less than the permitted maximum suspended solids concentration.

To illustrate, a plant taking in a feed containing 20mg/l and operating under a discharge permit of 40mg/l would be able to operating at a nominal, and acceptable 50% recovery. Given that the total suspended solids are a function of the feed water, and that the discharge levels are regulated by permit, it would be possible to control the overall recovery of the plant such that the discharge levels would not be exceeded. The configuration of the present invention facilitates such a degree of control and may substantially eliminate, or at least provide significant savings in, suspended solids disposal costs.

The plant configuration of the present invention means that it is not necessary to use flocculants or coagulants which add significantly to sludge disposal costs.

Description of the Invention

The invention will now be more particularly described with reference to the drawings. Specifically with reference to Figure 1, Item 1 represents the brine which is to be filtered. The brine is taken in by way of a feeder pump 2, which moves the brine along line 3, through pump 4, along line 5 and through valve 6, which during filtration is open leading the seawater into primary microfiltration or ultrafiltration unit 7. Feeder pump 2 may also include a coarse or pre-filtration device. In primary microfiltration or

ultrafiltration unit 7 are housed banks of modules of the type which have hollow fibres. The contaminated water passes along the outer side of the hollow fibres and produces clear water in the lumen of the fibres. The clear filtered water exits the primary micro-filtration or ultrafiltration unit at 9. In normal use, valve 10 is open and valve 11 is shut and the micro-filtered water, which is still saline, passes along line 12 to reverse osmosis unit 13. Reverse osmosis unit 13 desalinates the water and produces a desalinated stream of potable water 14 which can be collected for use. The residual, which includes a concentrated saline solution proceeds along line 15. In normal use valve 16 is shut and valve 17 is open and the concentrated saline solution moves along line 18 and back to be discharged into the brine.

During backwash mode valve 10 is shut and valve 11 is opened. Likewise valve 16 is open and valve 17 is shut. Thus, the reverse osmosis concentrate is forced along line 15, where upon it passes through a secondary micro-filtration or ultrafiltration unit 20 to produce a filtered saline solution which exits along line 21, moves through valve 11 and serves to backwash micro-filtration modules 8 because there is a positive pressure at 9 and one also at 5, and because valve 22 is open, the backwashed material which is dislodged from the filtration modules exits along line 23 and is returned to the brine solution.

It will be appreciated that when the material is operating in backwash mode, a source of pressure will be required to force the filtered concentrate back through the primary and secondary micro-filtration or ultrafiltration membrane modules for backwashing. This can be carried out in many ways. Reverse osmosis reject is often generally available at elevated pressures, and if this is the case, no additional separate pumping source is needed to deliver the reversed osmosis reject at a suitable pressure to backwash the membrane. However, if the reverse osmosis reject is not available at

sufficient pressure to backwash the membrane, it may be supplemented, by way of, for preference, a reservoir and pump located along line 21. In this regard, the filtered saline solution is allowed to accumulate in a CIP tank. The presence of a further reservoir and pump along line 12 will allow the reverse osmosis unit to operate in a continuous fashion.

A further filter can be incorporated either in line 23 to catch the material produced by backwashing, which can be concentrated down to a much smaller volume of water for sludge disposal.

By following this process, suspended materials which accumulate on the saline side of the reverse osmosis process (the reverse osmosis reject) are prevented from ever contacting the filtration side of the primary ultrafiltration membranes. Secondary micro-filtration or ultrafiltration unit 20 can also have an additional unit for cleaning by backwashing. This could be cleaned by way of a separate reservoir along line 21 which could be reserved and the contaminate flushed out back along line 16, 17 and 18 and out to waste.

In an alternative embodiment, filter 20 can be a cartridge filter, which may be disposable or replaceable. Alternatively, 20 can be a microfiltration or ultrafiltration unit with a cartridge on the feed side.

The use of reverse osmosis reject for backwashing has further benefits. The difference in salinity between the feed to the primary microfiltration or ultrafiltration membrane and the reverse osmosis reject, which has a much higher concentration of ionic species provides an osmotic shock effect that can kill bacteria growing on the microfiltration or ultrafiltration membrane. Using reverse osmosis reject can thus have a disinfecting effect on the primary MF or UF membranes.

Further, in preferred embodiments, acidic components or scale dispersants are added to the reverse osmosis feed, but subsequent to prefiltration in order to prevent scale precipitation in the reverse osmosis membrane. Thus, in this way, the reverse osmosis concentrate has a lower scale formation potential than the reverse osmosis feed.

Additionally, other benefits may also be realised. The apparatus of the present invention may be fitted with a conventional sand based prefilters to screen out large particles which may damage the primary microfiltration or ultrafiltration membranes (such as small parts of crustacean shells). The sand in such prefilters often acts as a support for the growth of algae and other micro-organisms. Because of this, the feed water into the primary microfiltration or ultrafiltration units, or at the very least the backwash for the sand prefilters, has typically needed to be chlorinated, to kill algae and other micro-organisms dislodged form the sand. In the present invention, because the backwash quality is high, it can be used as freely as desired to wash the primary microfiltration or ultrafiltration membranes. Thus, by the further addition of bactericidal agents, such as chlorine to the reverse osmosis reject at any point, in conjunction (additively or more preferably synergistically) with the osmotic shock effect caused, very high bacterial kills and resultant low bacterial content of the system can be registered without the need to chlorinate large volumes of intake seawater.